# ANNUAL MAXIMUM WIND SIMULATION BASED ON MOMENT PARAMETERS OF PARENT DISTRIBUTION

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## ABSTRACT

It has been revealed that higher moments of parent distributions influence the tail characteristics of annual maximum wind speed distribution. Some studies have been conducted to show that once the standard deviations of skewness and kurtosis of yearly variation for the 10 minute mean wind speeds are properly estimated, a good probability model for the annual maxima can be obtained. However since the parameters for four moments have various effects on the location and scale parameters of estimated Gumbel distribution for annual maxima, it is interesting to see more general relationship between those parameters of parent distributions and the location and scale parameters of Gumbel models. This paper aims at examining the characteristics of the moment parameters and their effects on the Gumbel models. Once the relation between the moment parameters and approximate annual maximum statistics is known, even a short period statistics such as 5 years or 10 years may help to have an approximate estimation of annual maximum. It is expected that such examinations of probabilistic characteristics of 10 minute mean wind speeds may provide good information for wind hazard models for individual sites.

## NOMENCLATURE

| | |
|---|---|
| $\mu$ | : Mean |
| $\sigma$ | : Standard deviation |
| $\gamma_1$ | : Skewness |
| $\gamma_2$ | : Unbiased kurtosis |
| $\kappa$ | : Shape parameter |
| $s$ | : Scale parameter |
| $l$ | : Location parameter |
| $F$ | : Cumulative probability function |

## 1. INTRODUCTION

In order to determine an appropriate design wind speed for structures, it is essential and important to estimate the probability distribution of annual maximum wind speeds. Gumbel model is often considered as a typical probability model for the distribution of annual maximum wind speeds in many loading standards. However, Frechet model may be preferred when the observed data includes some extreme phenomena, such as typhoons or hurricanes.

The maximum value of 10 minute mean wind speed is only one value among 52,560 samples in one year. However, it seems reasonable to assume that the statistical nature of 10 minute mean wind speeds, such as four moments, provide sufficient information corresponding to the characteristics of annual maximum extremes. When a sufficient number of data is available, the statistics of extremes may provide good models by simply applying the extreme value distribution theory. However, it has been reported that the four moments of parent distribution vary to suggest the non-identical nature and that the coefficients of variations of the third and fourth moments significantly contribute to the tail characteristics of annual maximum distribution [7].

In this paper, data of 10 minute mean wind speeds of every 3 hours for 155 meteorological sites are first utilized to identify the types of extreme value distribution models. A error between the fitting curve by Gumbel model and that by Frechet model (or Weibull model) is assumed to categorize the Gumbel model and the other two models. Then based on examining the shape parameter, Frechet or Weibull model can be determined. Categorization statistics are then obtained. And then correlations of yearly variations of four moments are examined. Regional variations of moment parameters are assumed by a parametrical study to investigate the effect of moment parameters on the tail characteristics of extreme value distributions. The polynomial translation method is applied to generate estimation of annual maximum wind speeds through the variation of moment parameters. Finally, the statistical data of 155 meteorological sites are utilized to simulate the annual maximum wind speeds. Statistical data of 5-year period is also utilized to estimate the annual maximum wind speed distribution.

## 2. IDENTIFICATION OF ANNUAL MAXIMUM WIND SPEEDS FOR 155 SITES

Generalized extreme value distribution model has been commonly used. The tail characteristics can be identified easily by fitting the shape parameter of the generalized model shown in Equation (1). That is, if the shape parameter approaches zero the distribution is considered Gumbel type; if it is identified positive, the distribution is considered Frechet type; if it is identified negative, Weibull model is preferred. However, when the shape parameter is very small, Gumbel type will be less different from the Weibull type. The same condition can also be observed for those Frechet models with very small parameters.

$$F(x) = \exp\left\{ -\left[ 1 + \kappa \left( \frac{x - l}{s} \right) \right]^{-\frac{1}{\kappa}} \right\} \quad (1)$$

$$E = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{\left( x_i - x_{G,i} \right)^2}{x_{G,i}^2} \right)} \quad (2)$$

$E$ : Fitting error

$n$ : Number of observed years

$x_i$ : i-th observed value at reduced variate $y_i$

$x_{G,i}$ : i-th value of generalized model at $y_i$

$y_i$ : i-th reduced variate on the Gumbel probability plot

To distinguish the types of extreme value distribution models, the error between models may be used. When the error between the fitting curve by Gumbel model and that by the Frechet model (or the Weibull) is smaller than 0.05, which represents an acceptable error defined by Equation (2), then the observed data may be considered as a Gumbel model. However, if the error is larger than 0.05 and the shape parameter fitted is positive, Frechet model may give a better fitness; if the error is larger than 0.05 and shape parameter is negative then Weibull model. By utilizing 155 meteorological sites in Japan, 155 errors between the fitting curve by Gumbel model and the curve by the Frechet or Weibull model are calculated by Equation (2). Among these 155 sites, there are 122 sites with an error smaller than 0.05 and considered as Gumbel model. 29 sites are regarded as Frechet model and 4 sites as Weibull model. If the errors between the observed data and the fitting curves are further examined and the value of 0.05 once again is considered as a criteria to distinguish a good fitness and a bad fitness, then there are 9 bad fitness for 122 sites of Gumbel model, 18 bad fitness for 29 sites of Frechet model and 2 bad fitness for 4 sites of Weibull model. Table 1 shows the results of categorization.

**Table 1 Statistics of type categorization**

| | Gumbel | Frechet | Weibull |
|---|---|---|---|
| Counts | 122 | 29 | 4 |
| Good fitness ($E < 0.05$): 126 | | | |
| Bad fitness ($E \geqq 0.05$): 29 | | | |

Figure 1 shows some sites with different categorizations. The fitting results of these sites were also shown by Fujino [1]. Fukuoka and Sumoto were categorized as Gumbel model in Reference [1]. However Sumoto is more like Frechet model in Figure 1(b). Matsumoto and Nagoya were considered as Frechet model in Reference [1] but Matsumoto is more like Gumbel model in Figure 1(c). Meanwhile, Aikawa and Sapporo are regarded as Gumbel model rather than Weibull model in Reference [1]. Such different fitting results also show in other sites.

The reason for the different fitting results may be the different observed period of time. In this paper, the observed period of statistical data of 155 sites is from 1961 to 2002 however the observed period in Reference [1] was from 1929 to 1977 or 1939 to 1977. The overlapping period is so short that it is hard to say the fitting results should be the same.

Some sites, Nagoshi and Okinoerabujima in Figure 2, are performed as Weibull model. However such sites of Weibull model are seldom occur. Fujino [1] proposed that since the error between the Gumbel and the Weibull model is very small, it might be suitable to categorized Weibull model as Gumbel model for simplicity.

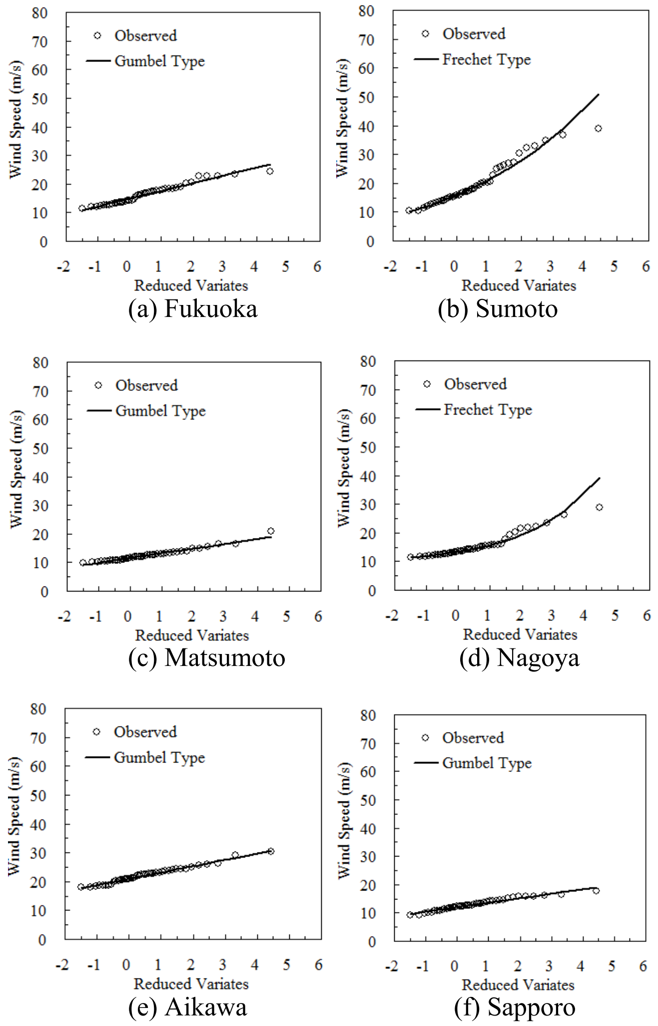



Figure 1 Fitting results for Fukuoka, Sumoto, Matsumoto, Nagoya, Aikawa, and Sapporo

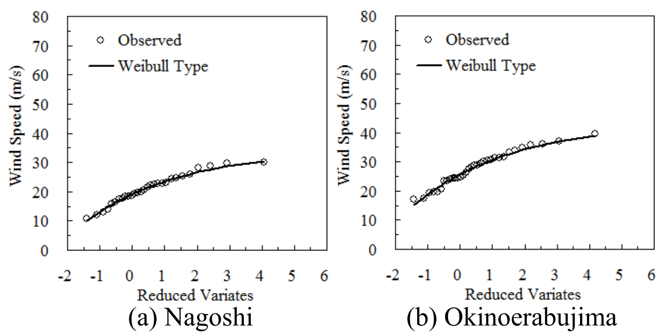



Figure 2 Fitting results for Nagoshi and Okinoerabujima

## 3. CHARACTERISTICS OF FOUR MOMENTS OF PARAENT DISTRIBUTION

### 3.1 Yearly variations of four moments

The distributions of four moments were examined. In all 155 sites, 10 minute mean wind speeds of every 3 hour data from 1961 to 2002 are utilized. From the yearly variation of four moments in each site, the correlation coefficients between four moments are calculated. Table 2 shows the mean and standard deviation value of the correlation coefficient values of four moments for 155 sites. Table 2 indicates a high correlation coefficient between yearly skewness and kurtosis. Figure 3 shows the histogram of 155 correlation coefficients which clearly indicates that in most sites, the high correlation exists in yearly $\gamma_1$ and $\gamma_2$.

**Table 2 Mean and standard deviation of correlation coefficients between four moments for 155 sites**

| | $\mu$-$\sigma$ | $\mu$-$\gamma_1$ | $\mu$-$\gamma_2$ | $\sigma$-$\gamma_1$ | $\sigma$-$\gamma_2$ | $\gamma_1$-$\gamma_2$ |
|---|---|---|---|---|---|---|
| mean | 0.59 | -0.09 | -0.06 | 0.17 | 0.09 | 0.91 |
| s.d. | 0.33 | 0.30 | 0.26 | 0.32 | 0.27 | 0.05 |

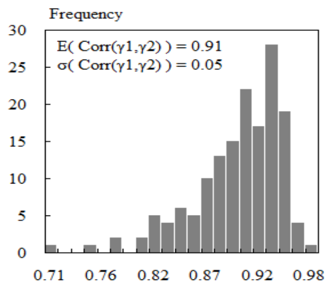
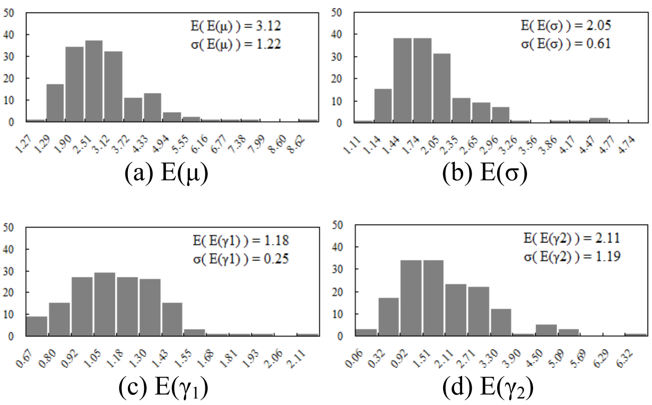



Figure 3 Histograms of 155 correlation coefficients between yearly skewness and kurtosis

### 3.2 Regional variations of moment parameters

The mean and the standard deviation of four moments for each site are calculated as moment parameters indicating the characteristics of regional variations of four moments. The histograms of the moment parameters for 155 sites are then plotted as Figure 4. In some sites the standard deviation of four moments is close to zero which suggests the identical nature for parent distributions, but in most sites the standard deviation is significant so that the identical hypothesis would be rejected.



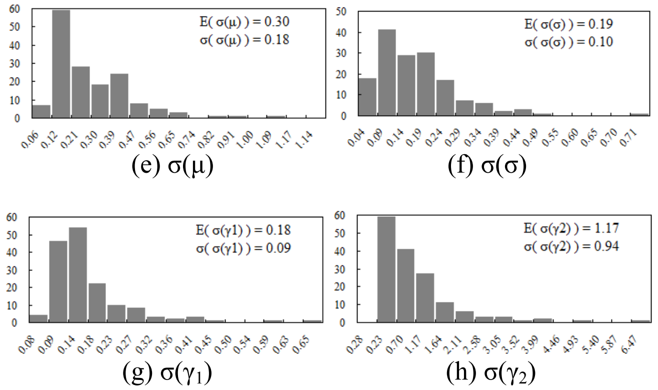



Figure 4 Histograms of mean and standard deviation of four moments for 155 sites

Table 3 shows the correlation coefficients between these 8 moment parameters of 155 sites, from which it can be clearly observed that a high correlation exists in E(μ) and E(σ), E($\gamma_1$) and E($\gamma_2$), σ(μ) and σ(σ), and σ($\gamma_1$) and σ($\gamma_2$), which are shown in bold type.

**Table 3 Correlation coefficients between moment parameters for 155 sites**

| | E(μ) | E(σ) | E(γ1) | E(γ2) | σ(μ) | σ(σ) | σ(γ1) | σ(γ2) |
|---|---|---|---|---|---|---|---|---|
| E(μ) | 1.00 | **0.92** | (0.53) | (0.22) | 0.40 | 0.42 | 0.15 | 0.05 |
| E(σ) | -- | 1.00 | (0.38) | (0.29) | 0.37 | 0.41 | (0.03) | (0.12) |
| E(γ1) | -- | -- | 1.00 | **0.72** | (0.18) | (0.17) | 0.11 | 0.18 |
| E(γ2) | -- | -- | -- | 1.00 | (0.02) | (0.04) | 0.70 | 0.74 |
| σ(μ) | -- | -- | -- | -- | 1.00 | **0.85** | 0.15 | 0.07 |
| σ(σ) | -- | -- | -- | -- | -- | 1.00 | 0.15 | 0.08 |
| σ(γ1) | -- | -- | -- | -- | -- | -- | 1.00 | **0.94** |
| σ(γ2) | -- | -- | -- | -- | -- | -- | -- | 1.00 |

※( . ) : negative value

It is then suggested that when the moment parameters are estimated to generate a set of four moments for one year's samples in the Mon de Carlo simulation, the characteristics aforementioned should be taken into consideration.

## 4. SIMULATION OF ANNUAL MAXIMUM WIND SPEEDS BY THE POLYNOMIAL TRANSLATION METHOD

### 4.1 Polynomial translation method

A procedure for the application of polynomial translation method was introduced by Choi and Kanda [3]. A set of random variables, $Y$, whose four moments are given, is written in a polynomial form with respect to a standard normal random variable, $X$, as

$$Y = a + bX + cX^2 + dX^3 \qquad (3)$$

The coefficients of the polynomial form can be obtained from the following equations,

$$E(Y) = a + c = 0 \qquad (4)$$

$$Var(Y) = b^2 + 6bd + 2c^2 + 15d^2 = 1 \qquad (5)$$

$$\gamma_1(Y) = 2c(b^2 + 24bd + 105d^2 + 2) \qquad (6)$$

$$\gamma_2(Y) = 24\{bd + c^2(1 + b^2 + 28bd) + d^2(12 + 48bd + 141c^2 + 225d^2)\} \qquad (7)$$

In order to solve Equation (4) ~ (7), an algorithm like the least square method for nonlinear parameters is needed. An available approximation was introduced by Edgeworth [6] to reduce the number of equations to solve Equation (4) ~ (7) simultaneously.

Based on the application of the polynomial translation method and the characteristics of four moments, a simulation procedure is proposed as Figure 5.

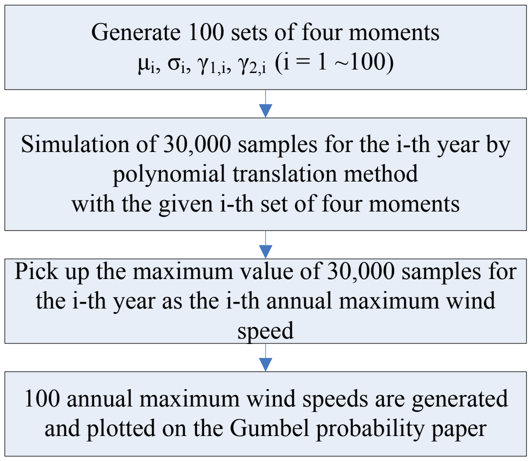



Figure 5 Simulation process for generating 100 annual maximum wind speeds

When the i-th set of four moments in step 1 is generated, a normal or a lognormal distribution with the mean and standard deviation of four moments can be applied according to the yearly variation of four moments. From Figure 3, since a high correlation exists in most sites, the generation of 100 sets of skewness and kurtosis are assumed as fully correlated based on the reality. Considering the randomness of the simulation results, simulation processes are carried out for several times and then the median values at each reduced variate are picked up as the best simulation result of 100 annual maximum wind speeds corresponding to 100 years of return period for design wind speeds.

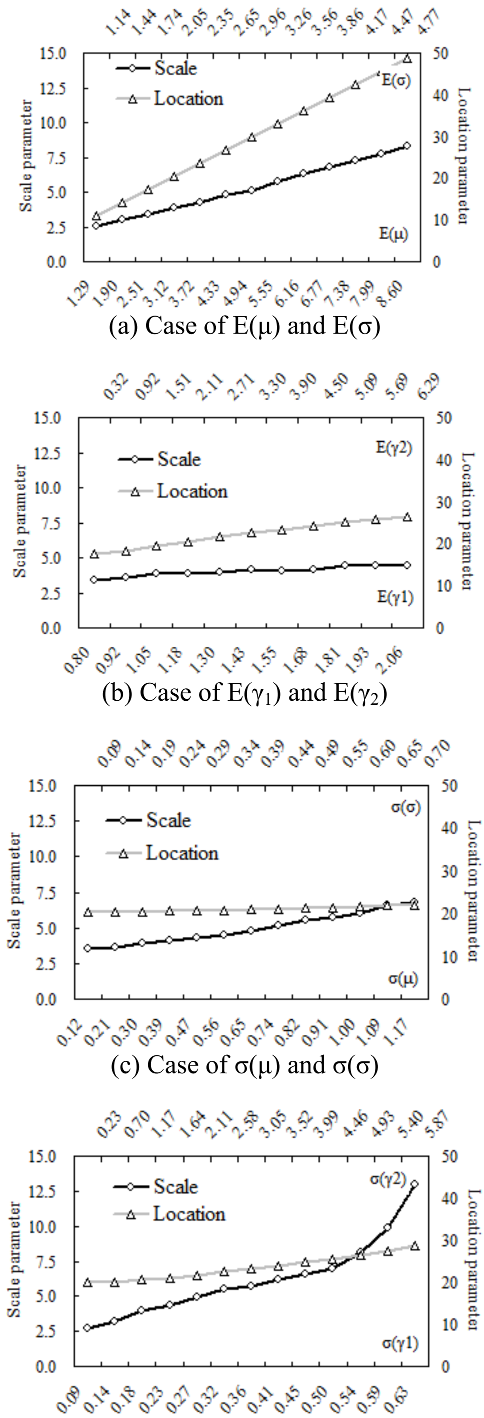
### 4.2 Effect of the regional variation of four moments

To generate a simulation results, which is fitted well to the observed data, the statistical nature of the four moments should be estimated properly. Table 3 indicates that the regional variations of four moments are highly correlated in reality and should be considered when generating 100 sets of four moments. To explain the effects of the regional variations on the extreme value distribution, 155 sets of mean and standard deviation of four moments are utilized in a parametric study.

Moment parameters are regarded as variables and vary as “regional mean + N × regional standard deviation”. N is an integer varying from negative to positive to generate the minimum value and the maximum value of moment parameters. However, when N is increasing from negative to positive, correlation between moment parameters should be taken into consideration. For example, when E(μ) increases, E(σ) increases at the same time. Therefore, there are four cases to investigate the effects of moment parameters, which are the pair of E(μ) and E(σ), E($\gamma_1$) and E($\gamma_2$), σ(μ) and σ(σ), and σ($\gamma_1$) and σ($\gamma_2$). Simulation processes are then carried out for 11 times and the median values are picked up as the best estimates to calculate the scale parameter and the location parameter by the moment method for simplicity. The probability distributions of four moments are assumed normal distribution.

The scale parameter and the location parameter are plotted with the regional variations of four cases in Figure 6. The upper and lower abscissas show the variations of correlated moment parameters in terms of the regional standard deviation from the regional mean, which corresponds to the horizontal abscissas shown in Figure 4.

For the variation of scale parameters shown in Figure 6, when the values of E(μ) and E(σ), σ(μ) and σ(σ), or σ($\gamma_1$) and σ($\gamma_2$) increase, the scale parameter also increases. Among these three cases, the case of σ($\gamma_1$) and σ($\gamma_2$), has rather significant effect than other two cases. For the variation of location parameters, location parameter increases when the values of E(μ) and E(σ) increase. In other cases, the variation of location parameters is not significant apparently. Once the moment parameters are properly estimated, the tail characteristics of extreme value distribution can be predicted through the examination of the scale and location parameters.




(a) Case of E(μ) and E(σ)

(b) Case of E($\gamma_1$) and E($\gamma_2$)

(c) Case of σ(μ) and σ(σ)

(d) Case of σ($\gamma_1$) and σ($\gamma_2$)

Figure 6 Gumbel parameters with four cases of moment parameters

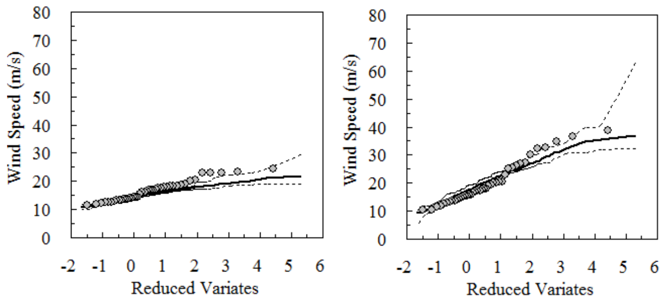
## 5. STATISTICS OF SIMULATION RESULTS OF 155 SITES

### 5.1 Case studies of simulation results

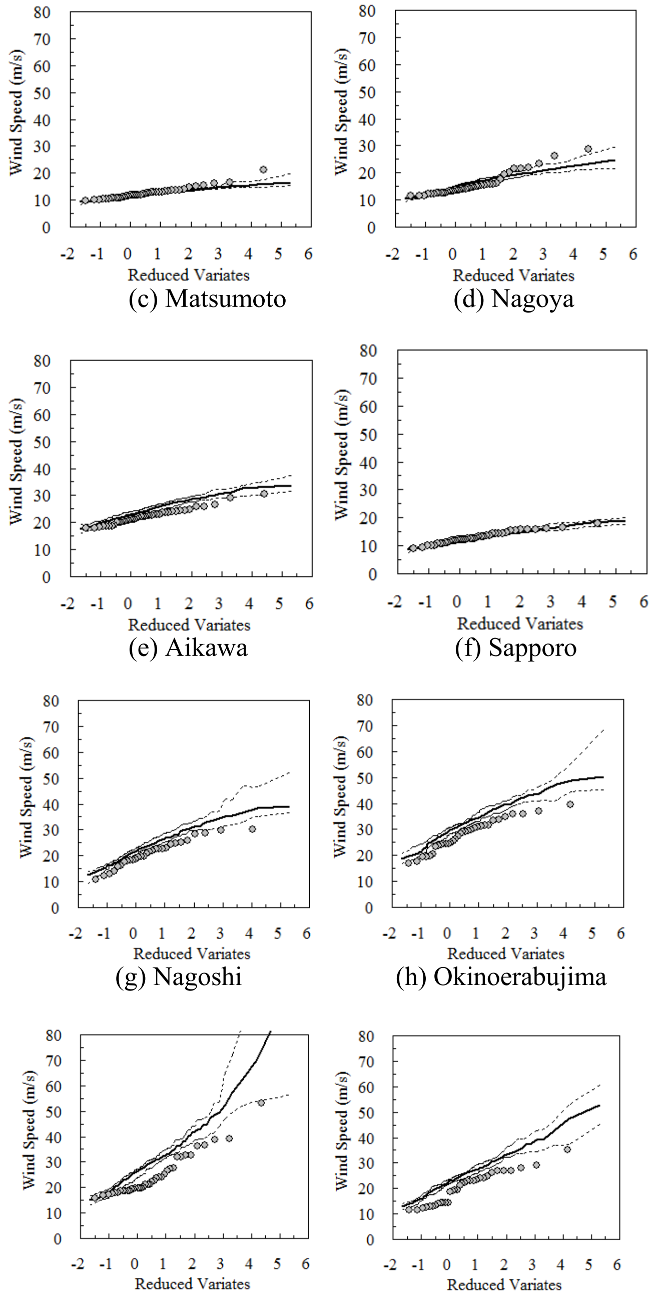
The simulation procedure is then applied to 155 sites with the same assumption of statistical nature of four moments as the previous sections, fully correlated skewness and kurtosis and normal distribution of probability distributions for four moments. Figure 7 shows the simulation results of 10 sites. The solid line indicates the median estimates of 11 sets of 100 annual maxima and the dotted lines indicate the upper and lower envelopes. The gray circles represents the observed data for specific site. Moment parameters of these 10 sites are listed in Table 4.

**Table 4 Moment parameters of 10 sites**

| Site | E(μ) | E(σ) | E(γ1) | E(γ2) |
|---|---|---|---|---|
| Fukuoka | 2.83 | 2.00 | 0.94 | 0.90 |
| Sumoto | 3.20 | 1.96 | 1.24 | 2.94 |
| Matsumoto | 2.25 | 1.92 | 1.17 | 0.81 |
| Nagoya | 2.89 | 1.88 | 1.12 | 1.56 |
| Aikawa | 4.32 | 3.33 | 1.31 | 1.40 |
| Sapporo | 2.51 | 1.71 | 0.94 | 0.88 |
| Nagoshi | 3.15 | 2.07 | 1.36 | 4.80 |
| Okinoerabujima | 5.49 | 2.78 | 1.12 | 3.84 |
| Ishigakijima | 4.51 | 2.15 | 1.28 | 6.32 |
| Kumijima | 3.70 | 1.96 | 0.92 | 5.05 |
| Site | σ(μ) | σ(σ) | σ(γ1) | σ(γ2) |
| Fukuoka | 0.13 | 0.12 | 0.15 | 0.77 |
| Sumoto | 0.45 | 0.45 | 0.28 | 2.29 |
| Matsumoto | 0.20 | 0.15 | 0.12 | 0.40 |
| Nagoya | 0.15 | 0.08 | 0.13 | 0.97 |
| Aikawa | 0.41 | 0.30 | 0.12 | 0.48 |
| Sapporo | 0.28 | 0.22 | 0.14 | 0.49 |
| Nagoshi | 0.59 | 0.25 | 0.45 | 3.39 |
| Okinoerabujima | 0.21 | 0.19 | 0.42 | 2.90 |
| Ishigakijima | 0.38 | 0.23 | 0.65 | 6.47 |
| Kumijima | 0.18 | 0.15 | 0.60 | 5.30 |




(a) Fukuoka (b) Sumoto




(c) Matsumoto (d) Nagoya (e) Aikawa (f) Sapporo (g) Nagoshi (h) Okinoerabujima (i) Ishigakijima (j) Kumijima

Figure 7 Simulation results and the observed data of 10 sites

From the simulation results, it is clearly observed that Fukuoka, Sumoto, Matsumoto, Nagoya, Aikawa and Sapporo show fairly good agreements with the observed data (E<0.1). However, the simulation results of Nagoshi, Okinoerabujima, Ishigakijima and Kumijima show rather significant error in the tail part of distributions, which may be resulted from rather high values of $E(\gamma_2)$ and $\sigma(\gamma_2)$ shown in Table 4. Error values between the observed data and the simulation results by Equation (2) for these 10 sites are listed in Table 5.

**Table 5 Errors between observed data and simulation results for 10 sites**

| Site | Error |
|---|---|
| Fukuoka | 0.1007 |
| Sumoto | 0.0927 |
| Matsumoto | 0.0634 |
| Nagoya | 0.0963 |
| Aikawa | 0.0910 |
| Sapporo | 0.0234 |
| Nagoshi | 0.1396 |
| Okinoerabujima | 0.1372 |
| Ishigakijima | 0.2122 |
| Kumijima | 0.2294 |

From the effects of moment parameters on the Gumbel parameters mentioned in the previous section, it is predictable that once larger values of $E(\gamma_2)$ and $\sigma(\gamma_2)$ are estimated, the scale parameter becomes large, in other words, the simulation results may perform as Frechet model. Figure 8 shows the relation between the observed annual maxima and the observed kurtosis by plotting the statistical data of Nagoshi, Okinoerabujima, Ishigakijima and Kumijima together. The tendency of the distribution shows a proportional relationship. The larger value of kurtosis may result in larger annual maximum values.

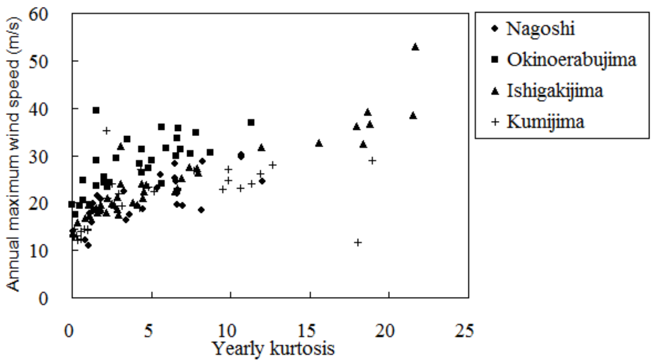
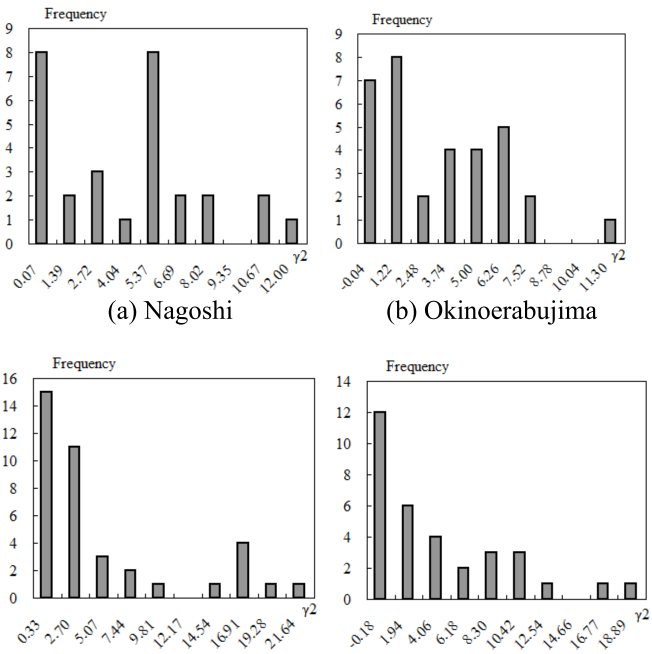



Figure 8 Distribution of observed annual maxima and yearly kurtosis for Nagoshi, Okinoerabujima, Ishigakijima and Kumijima

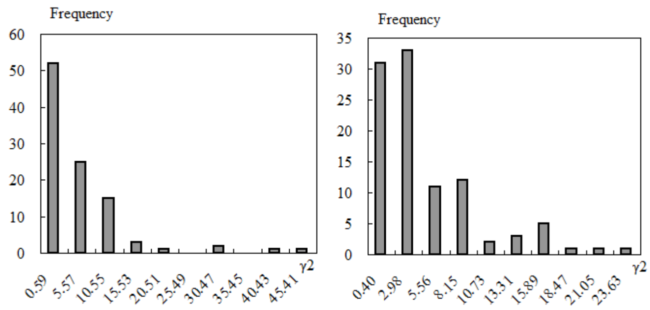
Figure 9 shows the histograms of the observed yearly kurtosis of these four sites. From the histograms shown in Figure 9, most observed kurtosis values are distributed in the lower value range, which makes the histograms more like the lognormal distribution than the normal distribution. Therefore when simulation process is carried out, 100 sets of higher moments should be generated as the lognormal distribution rather than the normal distribution. However, it is expected that a lognormal distribution has a longer tail than the normal distribution and the longer tail characteristics will surely result in a larger value of kurtosis and the larger value of simulated annual maxima. To avoid the extremely large value caused by the longer tail of lognormal distribution and represent the similar histograms of observed kurtosis, the lognormal distribution should be truncated by an upper bound. Figure 10 shows the histograms of generated kurtosis by the lognormal distribution and by the lognormal distribution truncated by an upper bound. The upper bound is assumed to be the maximum value of random samples by normal distribution with the same number of samples.




(a) Nagoshi (b) Okinoerabujima

(c) Ishigakijima (d) Kumijima

Figure 9 Histograms of observed yearly kurtosis

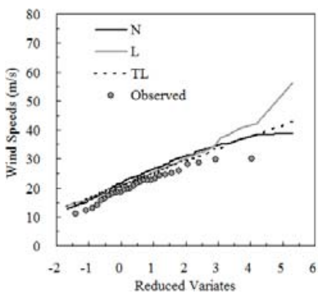



(a) Lognormal dist. (b) Truncated lognormal dist.

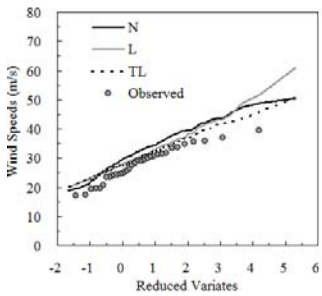
Figure 10 Histograms of generated yearly kurtosis in Ishigakijima

By applying the truncated lognormal distribution to generate 100 sets of higher moments in simulation process, simulation results of Nagoshi, Okinoerabujima, Ishigakijima and Kumijima are shown in Figure 11. The solid line, “N”, represents the median estimate of simulation results by normal distribution of higher moments. The gray line, “L”, represents the simulation results by lognormal distribution. The dashed line, “TL”, represents the simulation results by truncated lognormal distribution. Simulation results by truncated lognormal distribution in Nagoshi and Okinoerabujima do not show much difference from that by normal distribution. However the results in Ishigakijima and Kumijima show the simulations by truncated lognormal distribution largely reduce the errors between the median estimates and the observed data. The error is reduced from 0.2122 to 0.1124 for Ishigakijima and from 0.2294 to 0.1409 for Kumijima.

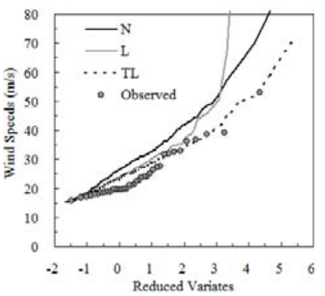
For extremely large values of estimated $E(\gamma_2)$ and $\sigma(\gamma_2)$, such as Ishigakijima and Kumijima, the truncated lognormal distribution of higher moments may be an improvement for simulation process. However, for those sites with normal estimated $E(\gamma_2)$ and $\sigma(\gamma_2)$, it seems good enough to assume the higher moments as normal distribution.



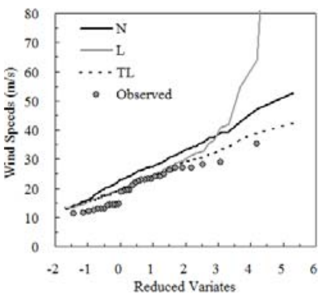
(a) Nagoshi



(b) Okinoerabujima



(c) Ishigakijima



(d) Kumijima

Figure 11 Simulation results different distribution of generated kurtosis

## 5.2 Simulation by short term period of statistical data

With good estimation of moment parameters, a simulation process based on polynomial translation method can provide a good agreement to the observed data. Then 5-year period of data for the two well-simulated sites, Aikawa and Sapporo, are used to estimate the mean of four moments and the standard deviation of four moments. The simulation is again proceeded to examine the agreement with observed statistics. Table 6 shows the statistical data of moment parameters in each 5 year period. The order of the 5 year periods is 1961~1965(P1), 1966~1970(P2), 1971~1975(P3), 1976~1980(P4), 1981~1985(P5), 1986~1990(P6), 1991~1995(P7), and 1996~2000(P8), which are listed in Table 6. Table 7 shows the errors of each period of the simulation results to the observed data.

**Table 6 Moment parameters of Aikawa and Sapporo with 5 year period of statistical data**

| Aikawa | E(μ) | E(σ) | E(γ1) | E(γ2) | σ(μ) | σ(σ) | σ(γ1) | σ(γ2) |
|---|---|---|---|---|---|---|---|---|
| P1 | 4.48 | 3.38 | 1.27 | 1.30 | 0.29 | 0.25 | 0.14 | 0.53 |
| P2 | 4.28 | 3.34 | 1.24 | 1.24 | 0.14 | 0.20 | 0.08 | 0.30 |
| P3 | 4.16 | 3.22 | 1.31 | 1.42 | 0.16 | 0.13 | 0.09 | 0.54 |
| P4 | 3.74 | 3.21 | 1.42 | 1.64 | 0.19 | 0.16 | 0.06 | 0.36 |
| P5 | 4.32 | 3.26 | 1.28 | 1.15 | 0.12 | 0.13 | 0.08 | 0.40 |
| P6 | 4.09 | 3.05 | 1.40 | 1.73 | 0.24 | 0.21 | 0.16 | 0.74 |
| P7 | 4.22 | 3.21 | 1.41 | 1.78 | 0.33 | 0.31 | 0.09 | 0.35 |
| P8 | 4.97 | 3.79 | 1.22 | 1.08 | 0.20 | 0.19 | 0.04 | 0.20 |
| Sapporo | E(μ) | E(σ) | E(γ1) | E(γ2) | σ(μ) | σ(σ) | σ(γ1) | σ(γ2) |
| P1 | 2.65 | 1.96 | 1.03 | 0.89 | 0.07 | 0.02 | 0.08 | 0.29 |
| P2 | 2.48 | 1.81 | 1.01 | 1.01 | 0.10 | 0.07 | 0.06 | 0.32 |
| P3 | 2.42 | 1.76 | 1.05 | 1.25 | 0.15 | 0.06 | 0.15 | 0.77 |
| P4 | 2.23 | 1.76 | 0.96 | 0.79 | 0.05 | 0.05 | 0.05 | 0.10 |
| P5 | 2.40 | 1.58 | 0.93 | 0.94 | 0.07 | 0.11 | 0.13 | 0.54 |
| P6 | 2.28 | 1.37 | 0.75 | 0.42 | 0.07 | 0.05 | 0.12 | 0.28 |
| P7 | 2.62 | 1.64 | 0.84 | 0.64 | 0.28 | 0.22 | 0.07 | 0.25 |
| P8 | 2.69 | 1.61 | 0.87 | 0.73 | 0.06 | 0.03 | 0.14 | 0.41 |

**Table 7 Errors of simulation results of Aikawa and Sapporo with 5 year period of statistical data**

| Period | Aikawa | Sapporo |
|---|---|---|
| P1 | 0.10 | 0.11 |
| P2 | 0.08 | 0.08 |
| P3 | 0.07 | 0.08 |
| P4 | 0.07 | 0.10 |
| P5 | 0.03 | 0.06 |
| P6 | 0.08 | 0.12 |
| P7 | 0.13 | 0.08 |
| P8 | 0.16 | 0.09 |

Most periods of Aikawa show fairly agreement with the observed data except for the period from 1996 to 2000. The low values of estimated moment parameters from 1996 to 2000 may provide an under estimates of annual maximum wind speed. Most periods of Sapporo show fairly good agreement with the observed annual maxima.

When a construction project is planned, wind speed measurements at the site are always encouraged. It is expected to take more than 5 to 10 years for a large project before the beginning of construction. Even when only a short period data is available, such information as the four moments of 10 minute mean wind speeds in certain period of years are considered to be meaningful for the estimation of annual maximum wind speed distribution. Even in cases when the direct estimation of the tail of extreme value distribution from the simulation based on a short period data may not be possible, it is useful as additional information to a macro-scale wind hazard map such as shown in AIJ load recommendations [2] for the determination of design wind speed.

## 6. CONCLUSIONS

The distributions of observed annual maximum wind speeds of 155 meteorological sites have been examined to distinguish the types of the extreme value distribution models. A common value for an acceptable engineering error, 0.05, is assumed to distinguish Gumbel model, Frechet and Weibull model. Among 155 sites, 122 sites are categorized as Gumbel model, 29 sites as Frechet model and other 4 sites as Weibull model. Some sites are also used to illustrate the fitness of types and compared to Fujino [1] to show the different fitting results.

The mean, standard deviation, skewness and kurtosis have been examined for 155 sites. The variations of four moment parameters are generally significant and the non-identical nature of the parent distribution is confirmed. When the yearly and regional variation of four moments are estimated for the simulation of annual maximum wind speeds by the polynomial translation method, good agreements are observed by the median estimate for the annual maximum wind speed distribution and the statistical annual maxima. Even in some extreme cases with significantly large value of standard deviation of higher moments, a truncated lognormal distribution for generating yearly higher moments can be assumed to provide a better agreement of annual maximum wind speeds to the observed data than the normal distribution.

It is also interesting that once the moment parameters are estimated properly, even short-term statistical data can fairly provide good agreements of simulation results to the observed data. Statistical data of Aikawa and Sapporo are utilized to show the fairly good agreements to the observed annual maximum wind speeds. In most cases, the errors between the simulation results and the observed data are smaller than 0.1 even the short-term period is only taken as 5 years.

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